Multiplexing Low and High QoS workloads in Virtual Environments

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Outline

Outline

Infrastructure management

IT infrastructure management is increasingly relying on virtualization

- Physical machines migrate to Virtual machines
- Deployed hardware agnostically using VMM
- VMM offer flexibility in :
  - Partitioning hardware resources
  - Isolation
  - Suspension
  - Migration
  - ...

Utilization

Virtualized servers require guaranteed availability and performance (high-QoS requirements)

- Static resource allocation
- Provisioning resources based on worst case requirements
- Resource usage varies
- Underutilized infrastructure

Utilization

How can we address underutilization?
Dynamically add low priority, low-QoS workloads

- Fill underutilized periods
- Virtualization gives flexibility
  - Start, stop, suspend, resume, migrate

High-QoS workloads must not suffer form being multiplex with low-QoS

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Resource and Job Model

Scheduling problems are researched in the context of the following model

- Infrastructure provider P
- Hosts a set of m identical machines M_j ($j = 1, \cdots, m$)
- Machine are able to execute any job from the set of n jobs J_i ($i = 1, \cdots, n$)
- Machine processing capacity s_j is $\forall i, j \in \{1, \cdots, m\} : s_i = s_j = 1$.
- A job models the execution of a virtual machine instance
  - Load patterns vary over time
  - Jobs are sequential
  - Release time r_i and duration p_i

Resource and Job Model

We consider two types of QoS levels for jobs

- High-QoS jobs
  - Must start at time r_i
  - Should be able to allocate the full processing power of the machine
  - Are not preemptible
- Low-QoS jobs
  - Can be started at any time
  - Can be preempted at a fixed cost c_p.
  - A resumption of a virtual machine instigates a cost c_r.
- The job startup costs (c_b) and termination costs (c_t) are also modeled
- An example of a low-QoS workload is a VM that executes low-priority CPU intensive batch jobs.

Resource and Job Model

- Machines correspond to a virtualized core of a server
- Infrastructure provider *P* hosts a cluster of servers
- Machines can accommodate more than 1 job at a time
- Distribution and allocation of virtual cores to VM is handled by the VMM
- Simple initial model
  - Focus on CPU usage alone
  - Do not model multiplexing overheads
  - I/O contentions, cache line misses...

VM Management Model

Managing VM distribution over multiple servers requires a *virtual infrastructure manager* (VIM)

- The VIM determines the available features
- Many different options
  - vSphere, Eucalyptus, OpenNebula, ...
- We chose OpenNebula
  - Open source, research platform, feature set generality...
  - Haizea scheduler used a basis for simulation
  - VM operations: *shutdown, start, suspend, resume and migrate*

Simulation framework

- Using the Haizea simulation backend
  - Discrete event simulation
  - Supports job type differentiation
- Solve underutilization using an overbooking approach
- Scheduler does not know runtime
- Active scheduling manages low-high QoS interference
- Compatible with OpenNebula

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Algorithm

- Reduce resource wastage while having a minimal impact on existing resource users.
- It is reasonable to assume high-QoS VMs do not continuously require all resources
- Goals
  - Only launch low-QoS when resources are available
  - Remove when interference might occur
  - Preserve performed work
    - VMs are uniquely suited (suspend, resume, migrate)
    - Overhead must be taking into account

Algorithm

- Simple and effective method to put restrictions on overbooking tolerance
  - Using just 3 parameters
  - Maximum amount of overbooked VMs
  - Lower bound: maximum server utilization when adding additional overbooked workloads
  - Upper bound: when should VMs start suspending
- Two steps:
  - Schedule new overbooking requests on suitable servers
  - Evaluate running requests and take appropriate actions if needed

Algorithm

Input: Set of nodes, Set of *vm_requests*, *lower_bound*
foreach *Node i* **do**
    if *Utilization(i)* $\leq$ *lower_bound* **then**
        available_nodes.add(*i*) ;
    end
end
Update(*vm_requests*) ;
while *available_nodes remaining & vm_requests remaining* **do**
    vm = *vm_requests*.pop() ;
    n = *available_nodes*.pop() ;
    Schedule(*vm* on Node *n*) ;
end

Algorithm 1: Adding Overbooked VMs

Algorithm

Input: Set of nodes, *upper_bound*

```
foreach Node i do
    if Utilization(i) ≥ upper_bound then
        vm = overbooked_vms(i).get_last() ;
        Suspend(vm) ;
    end
end
```

Algorithm 2: Suspending Overbooked VMs

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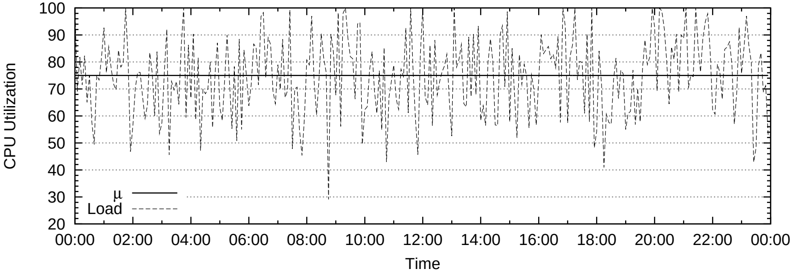
Load Patters

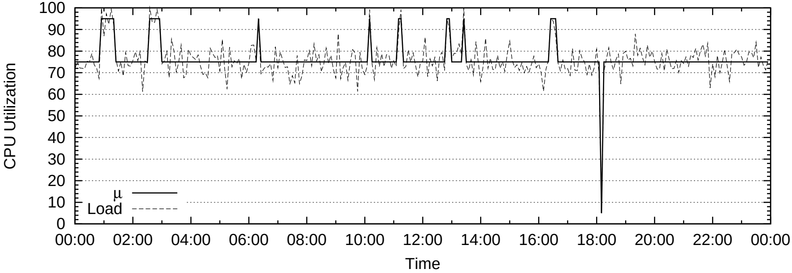
Three different load patters: noisy, spiky, business

Noisy: Starting from a mean utilization value μ, cpu load is generated by a normal distribution $N(\mu, 15)$.



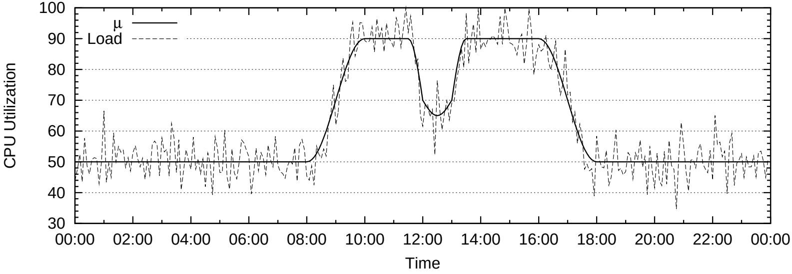
Load Patters

Spiky: This load pattern is based on a normal distribution with $\sigma = 5$. To add load spikes to the pattern, each drawing of the load distribution has 1% chance of generating a spike with 90% chance of having a positive one. Each spike has 50% chance of continuing.



Load Patters

Business: A function is used to determine the μ parameter of the normal distribution $N(\mu, 5)$ depending on the time of day. The value of μ is calculated with a piecewise function that represents utilization fluctuations coinciding with business hours.



Setup

- 50 homogenous octacore nodes
- Non-trivial synthetic load patters
- High-QoS
  - Each high-QoS application has an equal chance of generating one of the three load patterns
  - For spiky and noisy load patterns, μ is drawn from a normal distribution $N(75, 15)$.
  - The business load pattern, $min = 50$ and $max = 90$.
  - All cores are continuously occupied with high-QoS jobs
- Low-QoS
  - Each low-QoS job has a noisy load pattern with $\mu = 90$ simulating CPU intensive batch jobs

Setup

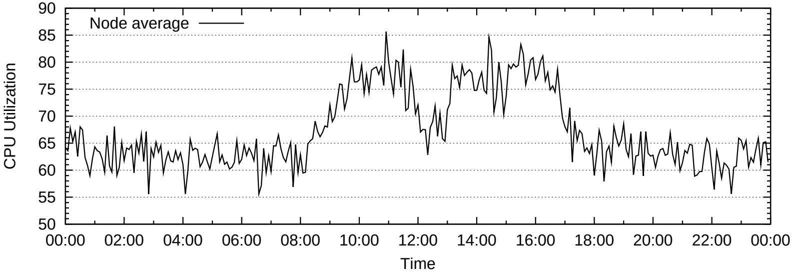


Figure: Sample load pattern on a single eight core node during a weekday.

Setup

All application runtimes are generated according to a geometrical distribution. If X is the runtime in minutes, the probability is expressed for $n = 30, 60, 90, ...$ with p equaling 0.1% and 1% for respectively high- and low-QoS applications.

$$Pr\left[X = n\right] = p\left(1 - p\right)^{\left(\frac{n}{30} - 1\right)} \qquad (1)$$

The costs for VM operations were configured as $c_b = c_p = c_r = c_t = 30s$.

Setup

- Executing without overbooking gives an average utilization of 69.4%
  = fairly high average utilization
- Every test is a variation on three parameters:
  - Max overbooked VMs either 1, 2 or 3
  - Upper bound in step of 5 between [85,95]
  - Lower bound in step of 5 between [60,80]
  - Minimum difference = 15%
  - Difference between bounds: window size

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Results

Average utilization can increase from 69.4% without overbooking to:

- 73.7% with max 1 overbooked VM and bounds [60,85]
  $\sim$ 400 suspends = 1 per day/server
- 87.3% with max 3 overbooked VMs and bounds [80,95]
  $\sim$ 8800 suspends = 25 per day/server

Results

Some trends can be observed across the different bound selections:

- With low bounds max overbooked VMs has low impact
- Moving from max 1 to 2 overbooked VMs results in fewer suspend for similar utilization gains
- Increasing from max 2 to 3 results in more suspends an little to no utilization gains
- For the current setup we find that max 2 is the optimal choice

Results

Increasing the lower bound with a constant higher bound:

- Utilization gains decrease slowly
- Suspends increase exponentially
- Lower bound determines suspend/utilization factor

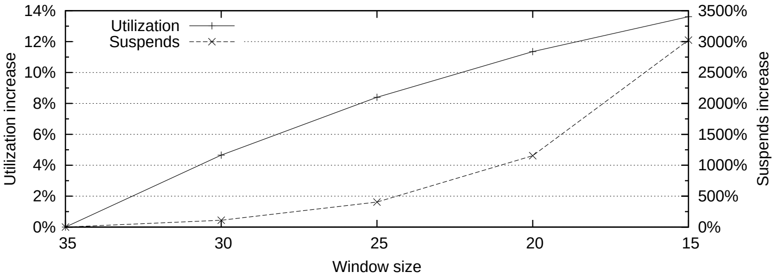

Figure: Increase in utilization and suspensions when using 2 overbooking slots and an upper bound of 95. The lower bound is increased to decrease the overbooking window.

Results

Increasing the upper bound with a fixed window size results in:

- A linear increase in utilization

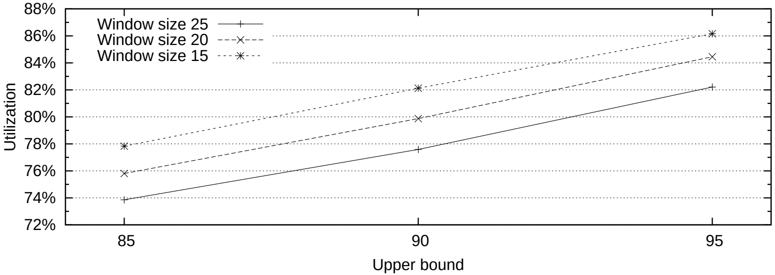

Figure: Utilization with two overbooking slots and varying upper bounds.

Results

- Roughly the same amount of suspends

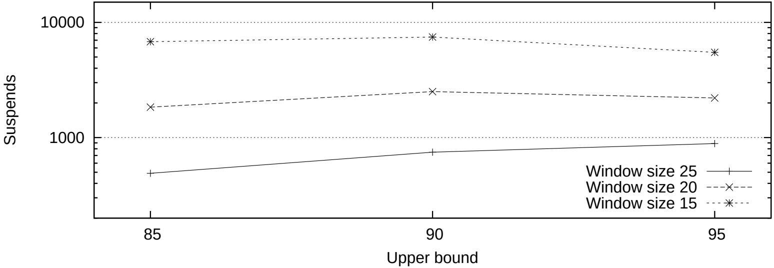

Figure: Suspensions with two overbooking slots and varying upper bounds and windows.

The selection of a correct upper bound will depend on factors not yet explored in the current simulation.

Outline

CPU intensive benchmark

- Dual socket quad core Intel Xeon
- CPU limited

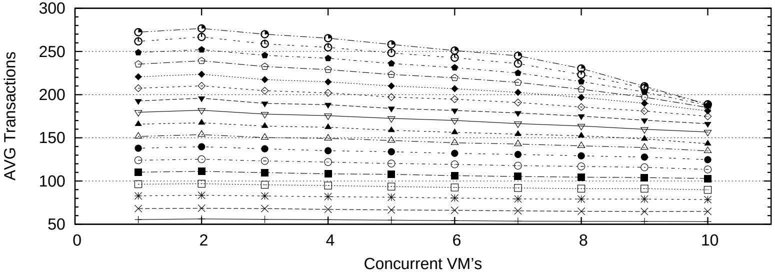

Figure: Sysbench scaling using both cpu and rate limiting with increasing VM amount

Analysis

- With 8 VMs we top off at about 240 transactions/second and 95% utilization per VM
- With 9 VMs we top off at about 220 transactions/second and 87% utilization per VM
- With 8 VMs, 220 transactions generates about 85% utilization per VM
- This is roughly the most conservative setup in the simulator which gained about 4% utilization

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Future Work

- Add a more complex VM/VMM interaction model
- Use real world load trace data
- Create more accurate model (memory, network, ...)
- Implement complexer scheduling algorithms
- Compare with real world experiments using OpenNebula

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Conclusion

- There are opportunities to increase utilization by monitoring the difference between formal and actual requirements
- Low-QoS workload overbooking can lower underutilization while having a manageable impact
- Scheduling policies can be simple and effective using a limited number of parameters
- An optimal selection of parameters can be made depending on the requirements

Questions?